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ARTICLE

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Potentials of a new laser guidance system for percutaneous musculoskeletal procedures

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Abstract Early experience using a new laser guidance device to assist CT-guided percutaneous musculoskeletal procedures is presented. We describe six cases, which demonstrate typical musculoskeletal applications of laser guidance. In our experience laser guidance for these procedures resulted in improved accuracy with no significant increase in biopsy time when a short learning period is considered. Other musculoskeletal procedures may benefit from laser guidance in preference to current standard CT-guided techniques, particularly when precision and accuracy are essential.

Key words Laser guidance · CT-guided percutaneous biopsy

Introduction

CT-guided biopsy is a widely accepted method of biopsy in the chest and abdomen. Recently, bone and joint CT-guided procedures have become more commonplace [1–5]. While a variety of guidance systems for CT biopsies are reported [6–11], most procedures are performed freehand. Although stereotactic systems are commonly used for localizing brain lesions, experience in other parts of the body is relatively limited [6, 9, 12]. We report the use of a laser guidance system for a variety of musculoskeletal procedures. Early experiences indicate that laser guidance facilitates performance of CT-guided needle placement in musculoskeletal procedures.

Materials and methods

The laser guidance system used is an experimental system in the final stage of research and development (ImaRx Pharmaceutical Corporation, Tucson, Ariz.). The system consists of a mobile apparatus and contains a tiny helium-neon diode laser (HeNe model CPM, Power Technology, Little Rock, Ariz.) at the end of a long arm (Optical Rail 07ORN005, Melles Griot, Irvine, Calif.). The laser is mounted on two precision rotational stages (model M481 stage, Newport Corporation, Irvine, Calif.), which are coupled to a precise translational stage (model 460 A-XY Newport Corporation). The system has the capability of aiming the laser beam through virtually 360° of the *x*, *y*, and *z* planes (Figs. 1, 2).

The laser guidance system utilized has Human Subjects Committee approval at our institution. In all cases the following conventional steps for set-up of CT biopsy were utilized. Informed consent was obtained and initial limited CT scanning was performed through the area of interest. After review of initial CT images, entry site and biopsy path, including needle trajectory angles and depth to lesion, were automatically calculated on the monitor by standard software included in most modern CT scanners. In these cases a Picker PQ 2000 (Highland Heights, Ohio) and a Siemens Somatom Plus DRH (Islin, N.J.) were used. One percent lidocaine was used as local anesthesia, except for one case which also required general anesthesia, and sterile technique was maintained throughout the procedures. After CT localization imaging with a surface grid in place, the skin entry site was marked with a felt marker pen. The sagittal angle (or angle from a line perpendicular to the floor with respect to craniocaudad direction) was set on the sagittal laser guide rotational stage. The axial angle (or angle from a line perpendicular to the floor with respect to the transverse plane, i.e., left/right across the patient's body) was set on the axial laser guide rotational stage. These two angles are the same needle trajectory angles provided by the biopsy planning on the CT monitor described above. The CT table was retracted out of the gantry and the laser guidance system was moved into position so that the laser beam was pointing directly at the skin entry site. The biopsy needle tip was placed at the skin entry site and the hub of the needle was placed directly in the path of the laser beam so that it shone on the back end of the needle hub. Subsequently the needle was advanced to the predetermined depth while keeping the laser beam spot on the center of the back end of the needle hub. By this technique, the coaxial nature of the laser set-up guides the needle pass to the exact desired target position.

Our preliminary work with the laser guidance system using animal muscle as phantoms indicates significant improvement in accuracy over freehand CT-guided needle placement in the tested biopsy

Fig. 1 Laser guidance device adjacent to CT scanner

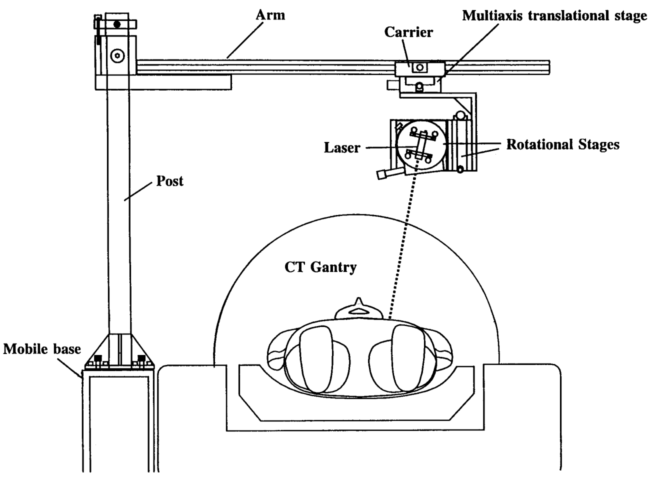


Fig. 2 Diagram of major components of laser guidance device

scenarios. Specifically, 180 needle placements were performed by two separate operators at 0°, 30°, and 60° angles with and without laser guidance. In addition, two separate compound angles of 25° sagittal angle with 30° axial angle, and 25° sagittal angle with 60° axial angle were also tested [13].

Case reports

Case 1

A 48-year-old woman with a past medical history of breast cancer complained of suffering back pain for 1 month. MRI of the lumbar spine revealed an infiltrating lesion of the T12 vertebral body. CT revealed a mixed lytic/sclerotic lesion. Laser-guided biopsy with a Jamshide needle was performed (10° sagittal angle, 22° axial angle, 7 cm depth to lesion; Fig. 3). The sample was very bloody and therefore the cytopathologist present asked for more tissue to assure adequate sample for diagnosis. Two Craig needle (American V. Mueller, McGaw Park, Ill.) passes were then laser guided into the lesion. Final histopathologic analysis of biopsy specimens revealed metastatic breast carcinoma in all samples.

Case 2

A 61-year-old woman with multiple presumed metastatic vertebral lesions by MRI underwent freehand CT-guided biopsy of an L4 vertebral lesion by transpedicular approach. The attempt did not contain a diagnostic sample. Subsequent passes were not attempted due to the difficult double-angle approach through the pedicle and the risk of nerve root injury by standard freehand CT-guided biopsy. Repeat transpedicular L4 biopsy was performed at similar angles and depth using laser guidance and a Craig needle (30° axial angle, 11 cm depth). Histopathologic analysis showed granulomatous lesions consistent with sarcoidosis. The diagnosis was suspect because of the unusual clinical presentation, and a stereotactic biopsy of a skull lesion utilizing a stereotactic head frame (Howmedica Leibinger, Dallas, Tex.) was performed by neurosurgery, which also yielded the diagnosis of sarcoidosis.

Case 3

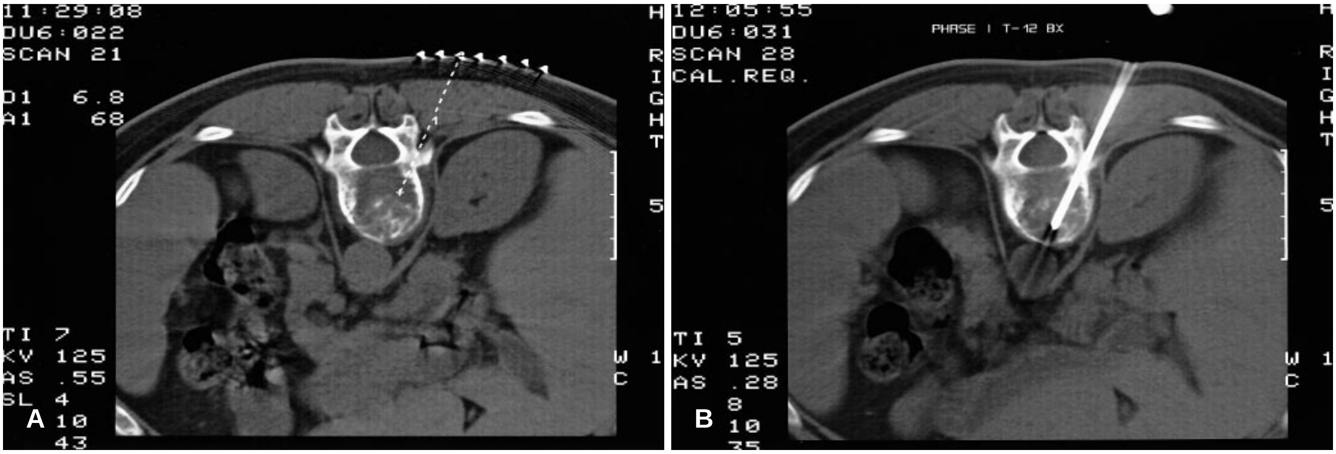
An 18-year-old woman complained of hip pain for 3 months. Physical examination revealed tenderness of the right sacroiliac (SI) joint. CT of the SI joints demonstrated mixed sclerotic/lytic lesion involving the iliac side of the right SI joint. In this case general anesthesia was administered by anesthesiology in the CT suite. Laser-guided biopsy was performed with a Craig needle system due to the limited angle range that would allow entrance into the SI joint. Also, the angle of inclination of the SI joint changed significantly with small (5 mm) changes in cranio-caudad level. Histopathologic analysis of obtained specimens was compatible with chronic inflammation. Open biopsy performed by orthopedics yielded the same histology. Cultures were negative, but the patient was placed on antibiotic therapy because chronic infection could not be excluded. She responded well without recurrent symptoms.

Case 4

A 42-year-old man with history of sacral chordoma, resected twice, developed right sternoclavicular joint pain and swelling. Plain radiographs revealed a destructive process in the right sternoclavicular joint, suggesting infection. Laser-guided biopsy with an 18-G Bernardino-Sones biopsy needle using 0° sagittal angle, 30° axial angle, and 4 cm depth revealed *Staphylococcus aureus* on microbiology studies.

Case 5

A 37-year-old woman with chronic low back pain was scheduled for steroid injection of bilateral SI joints. Two freehand CT-guided nee-



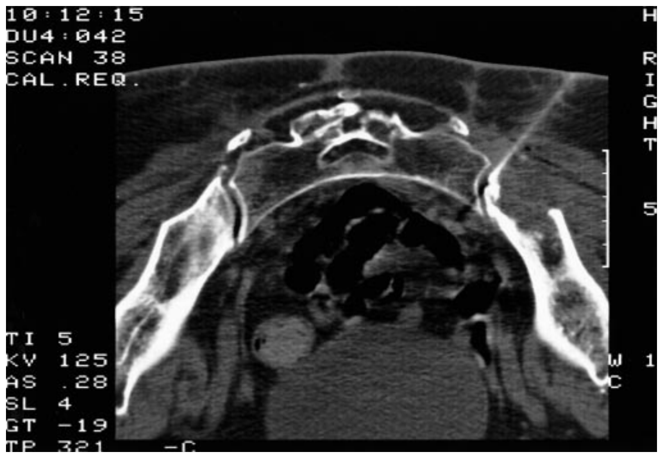


Fig. 3A, B Laser-guided biopsy of T12 vertebral body lesion. **A** Biopsy planned path plotted on cathode ray tube (CRT) monitor with surface grid in place (distance to lesion edge, *D1*=6.8 cm; axial angle, *A1*=22° from vertical; sagittal angle, *GT*=10° from vertical). **B** CT scan of actual first-pass Jamshide needle placement

Fig. 4 First-pass needle placement with tip of spinal needle in right SI joint (distance approx. 7 cm; axial angle 39°; sagittal angle 19°)

dle passes did not provide adequate needle position for injection due to different inclination of the joints with small level changes. Laser guidance was then utilized for successful 22-G spinal needle placement. The patient did not respond to the injections and underwent anterior L5-S1 diskectomy and fusion.

Case 6

A 68-year-old woman with multiple prior back surgeries had continued low back pain. To exclude SI joint pain as a cause of the patient's low back pain, bilateral SI joint injections were performed by the orthopedic surgeon in his office freehand with a combination local anesthetic/steroid solution. The orthopedic surgeon then asked for CT-guided SI joint injections to confirm appropriate needle placement. Using a 22-G spinal needle, the left SI joint was injected using freehand CT-guided needle placement, which required five separate passes and 45 min before the needle was placed accurately in the joint space (19° sagittal angle, 7° axial angle, approx. 7 cm depth). Laser guidance was then used to assist CT-guided 22-G spinal needle placement in the right SI joint (19° sagittal angle, 39° axial angle, approx. 7 cm depth; Fig. 4). The right SI joint required only one pass and 10 min for accurate needle placement. Successful needle placement within the SI joints was documented by post-needle-placement CT scans. The patient did not experience pain relief with the injections and a revision of her prior back surgeries was planned.

Discussion

Successful first-pass accurate needle placement was achieved utilizing laser guidance to assist conventional CT-guided musculoskeletal procedures. Initial clinical cases appear to substantiate the findings of prior phantom studies [13]. Percutaneous biopsy of musculoskeletal lesions is a well-established, safe, economical, and well-tolerated method for histopathologic and microbiologic diagnosis, with accuracy ranging from 68% to 100% [5]. Although fluoroscopy and ultrasonography operate in real time and are usually less expensive, CT-guided procedures may be advantageous in certain situations. Soft tissues are well demonstrated by CT, and this may aid in avoidance of critical structures (i.e., nerves and arteries) during needle placement. CT is often superior to fluoroscopy at showing the intrinsic structural variation of an osseous lesion. Ultrasonography shows only the extrinsic osseous morphology and inadequately demonstrates most bony lesions.

Several factors may make percutaneous bone biopsies difficult. These include inconvenient needle path, proximity of lesions to vital or critical anatomic structures, difficulties in penetrating hard bone, and hypervascular lesions. Biopsies of vertebral lesions may be complicated by paraplegia and tetraparesis due to neurological damage

[14, 15]. In the thoracic region pneumothorax becomes an additional risk. If the lesion is close to a vascular structure, hemorrhage may result as a severe complication. Use of a laser guidance system with CT could reduce or eliminate some of the previously described difficulties. Already stereotactic systems, which offer some of the same advantages as laser guidance, are reported to increase accuracy, allowing safer targeting of dangerously located lesions [6, 12, 16]. Conventional biopsy of small lesions may require more than one pass to reach the target [8]. Laser guidance systems may significantly reduce the number of passes necessary to reach such lesions, which could result in fewer complications [10].

One must realize that the laser does not simply point to the correct skin entry site. Using simple geometry the laser beam is adjusted to the correct angles that point a straight line from the skin entry site to the hidden target beneath the skin surface. By maintaining the laser beam spot on the back of the needle hub end as one advances the needle, the correct trajectory to the intended target is assured by the coaxial nature of the laser set-up. As with conventional biopsy techniques, if the patient moves after the skin entry is marked, an erroneous course is certain. However, to prevent this we use the laser guide to help place the numbing needle along the initial extent of our intended trajectory. We detach the needle from the syringe and obtain a single CT scan, which adds at most 2 min to procedure time. This scan verifies that the chosen needle trajectory is correct and is the path numbed, and that the laser guide is set up properly. This also verifies that the patient has not moved since the initial skin entry was marked. If the patient was to move after this verification scan, a conventional biopsy attempt would probably miss its intended target and could potentially be harmful. However, the laser guide would indicate that the patient had moved as the laser would no longer shine directly on the skin entry site or the verification needle.

There is a short learning curve in utilizing the laser guide, as maintaining the laser spot on the back end of the needle hub while advancing the needle requires some hand-eye coordination. Based on our initial clinical experience, we believe that overall time spent performing procedures that require difficult needle placement is substantially shortened. Miaux's series utilizing laser guidance in the body supports this hypothesis [10]. Prospective randomized trials of CT laser-guided procedures are now in progress at our institution.

We also believe that accurate and rapid needle placement will be the keys to performing more sophisticated skeletal procedures percutaneously. Recently, several authors have reported percutaneous resection of osteoid osteomas [17, 18], a procedure that requires precise localization of the nidus for successful treatment. In such cases, where accuracy of the localization is critical and needle placement is difficult, laser guidance or other accurate localization techniques will be particularly useful.

In conclusion, although the number of cases reported so far is relatively small, our preliminary findings show that laser guidance facilitates accurate needle placement. We find this especially useful in the previously mentioned musculoskeletal percutaneous procedures and foresee additional circumstances where laser guidance may be beneficial.

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